



Blade design and other activities in the Aeroelastic Design Group

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Blade Design and other activities in the Aeroelastic Design Group

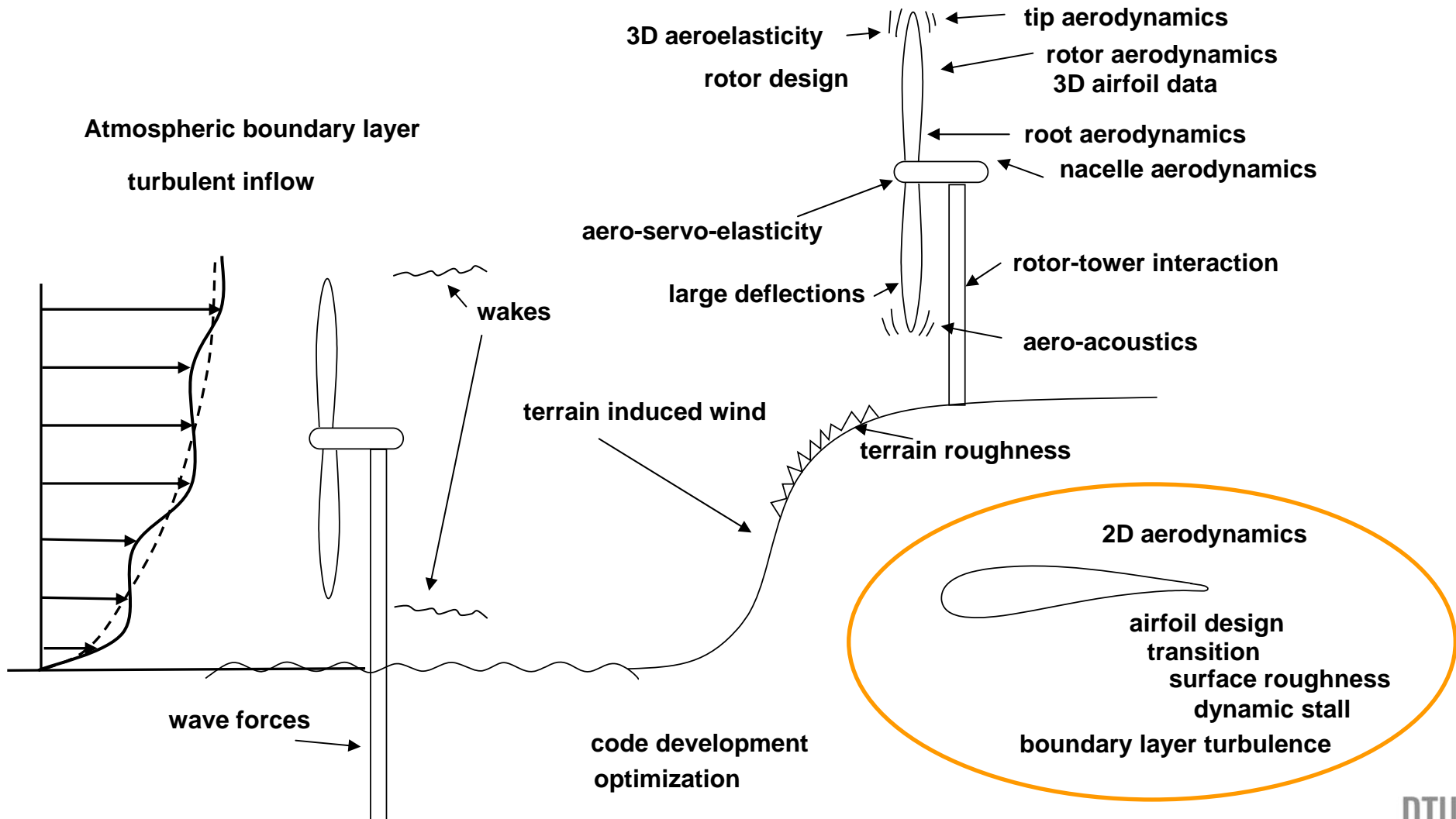
Christian Bak
Senior Scientist
Aeroelastic Design Group
Wind Energy Division
Risø DTU

Motivation

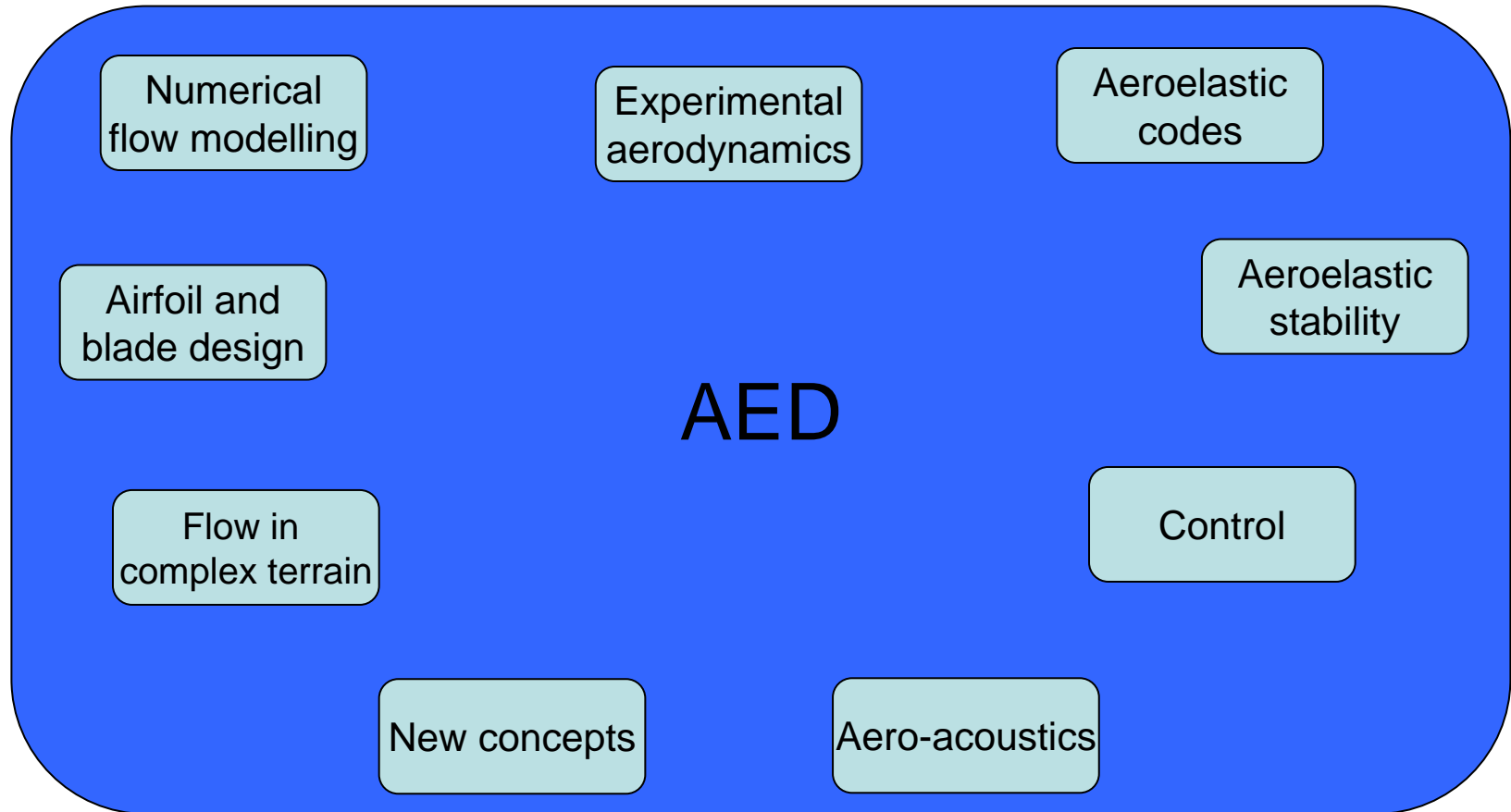
- "Aeroelasticity" is the interaction between:
 - the aerodynamics, which is the dynamics and forces created by the flow and
 - the elastic structure, which consists of blades , nacelle and tower
- Aeroelasticity? Why bother?



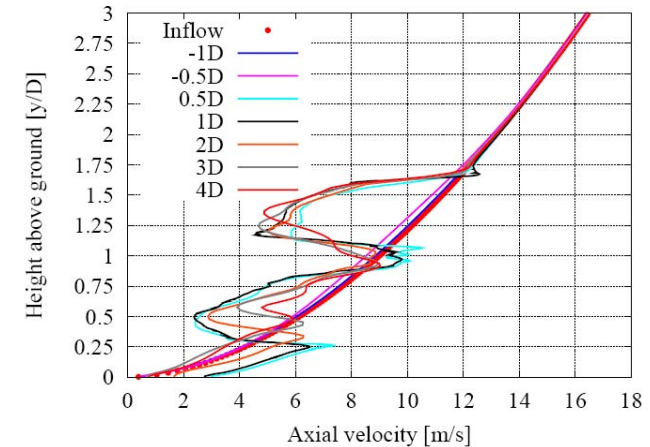
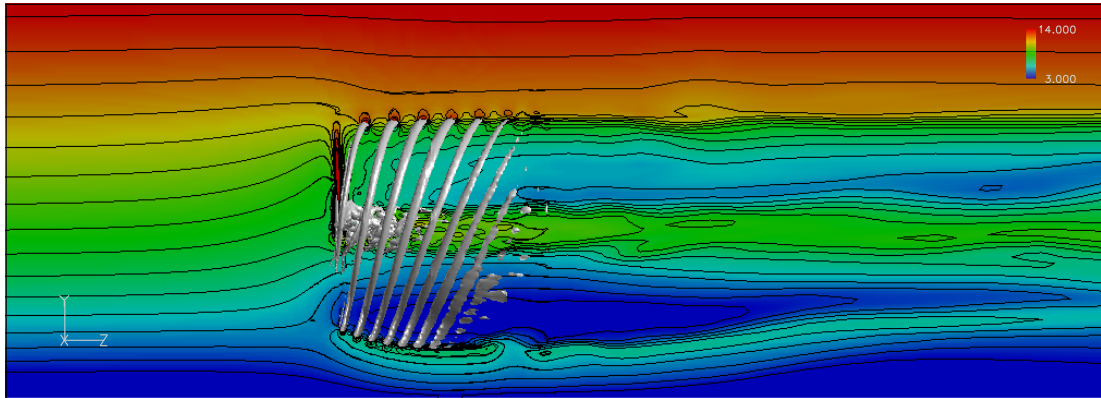
Schematic overview



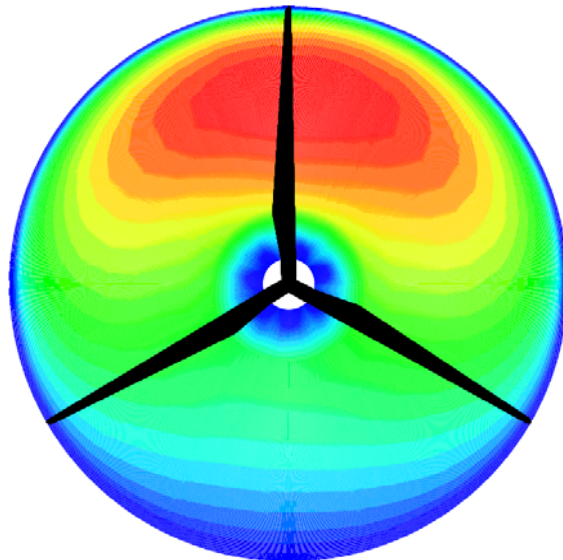
The Aeroelastic Design Group



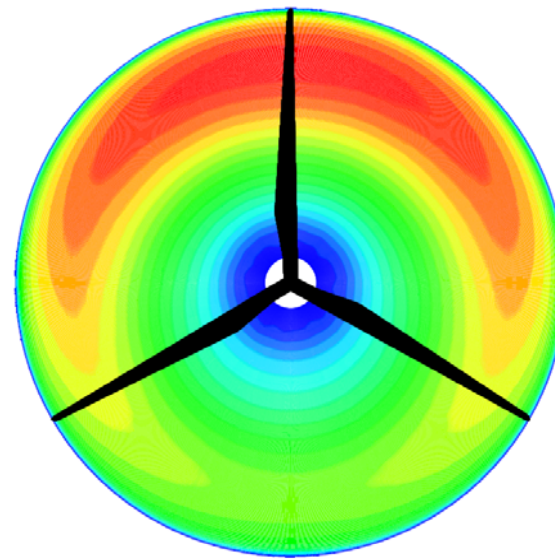
CFD Simulation of a rotor operating in shear



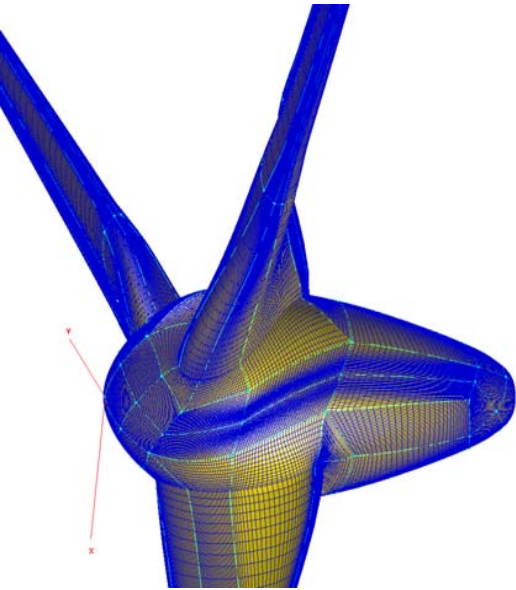
Rotor torque distribution over one revolution



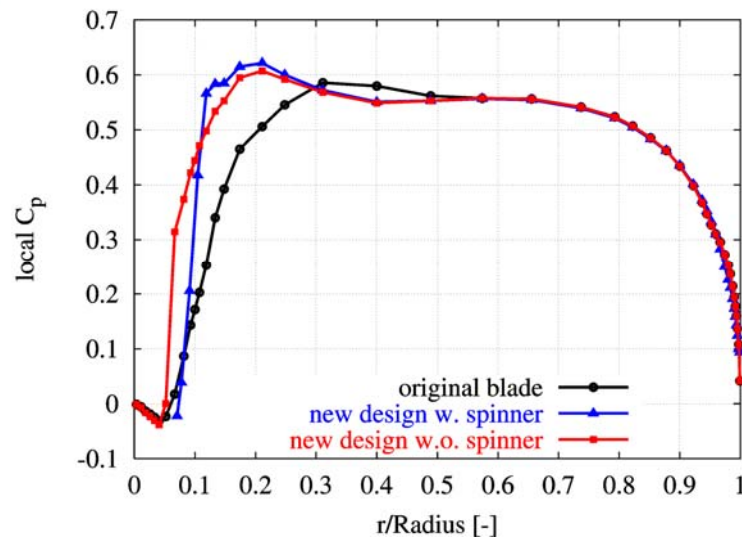
Rotor thrust distribution over one revolution



Advanced aerodynamic rotor design

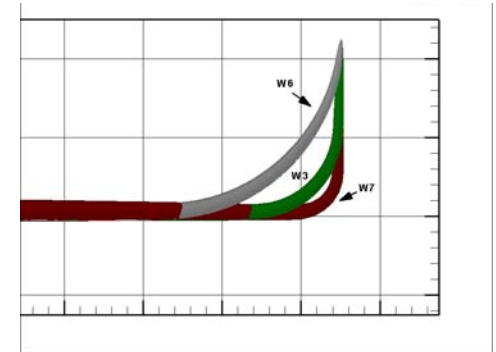
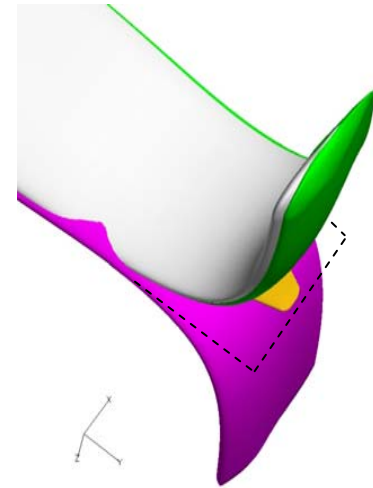


local power coefficient, C_p



Locally more power can be generated
Globally the gain is minimal
The cost is slightly larger loads

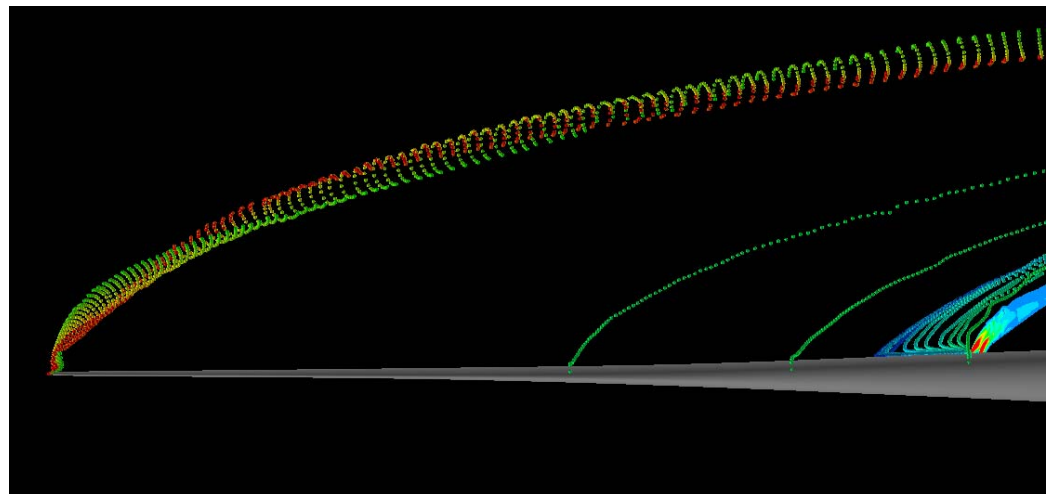
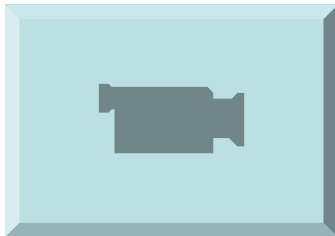
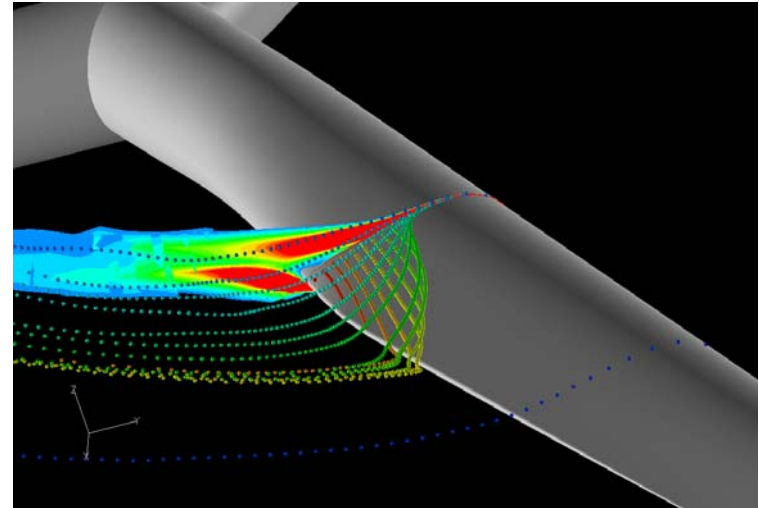
Increased exploitation of rotor area using winglets



Increases power (~1.7%)
Cost is (again!) increased loads

Details of the unsteady flow along the blade

- We can study the unsteady flow at all positions along the blade.
- Here showing the unsteady flow in the root section as well as the tip vortex.
- Due to the shear inflow the incidence of the blade changes over one revolution.



Airfoil series designed at Risø

- Risø-A1 (15% to 30%)
- Risø-P (12% to 24%)
- Risø-B1 (15% to 53%)

Aeroelastic computations - large deflections

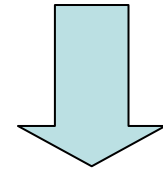
Tjæreborg 10 m/s



Wind modeling incl.
turbulence

Aerodynamics

Structural dynamics



Wind turbine load
response in time

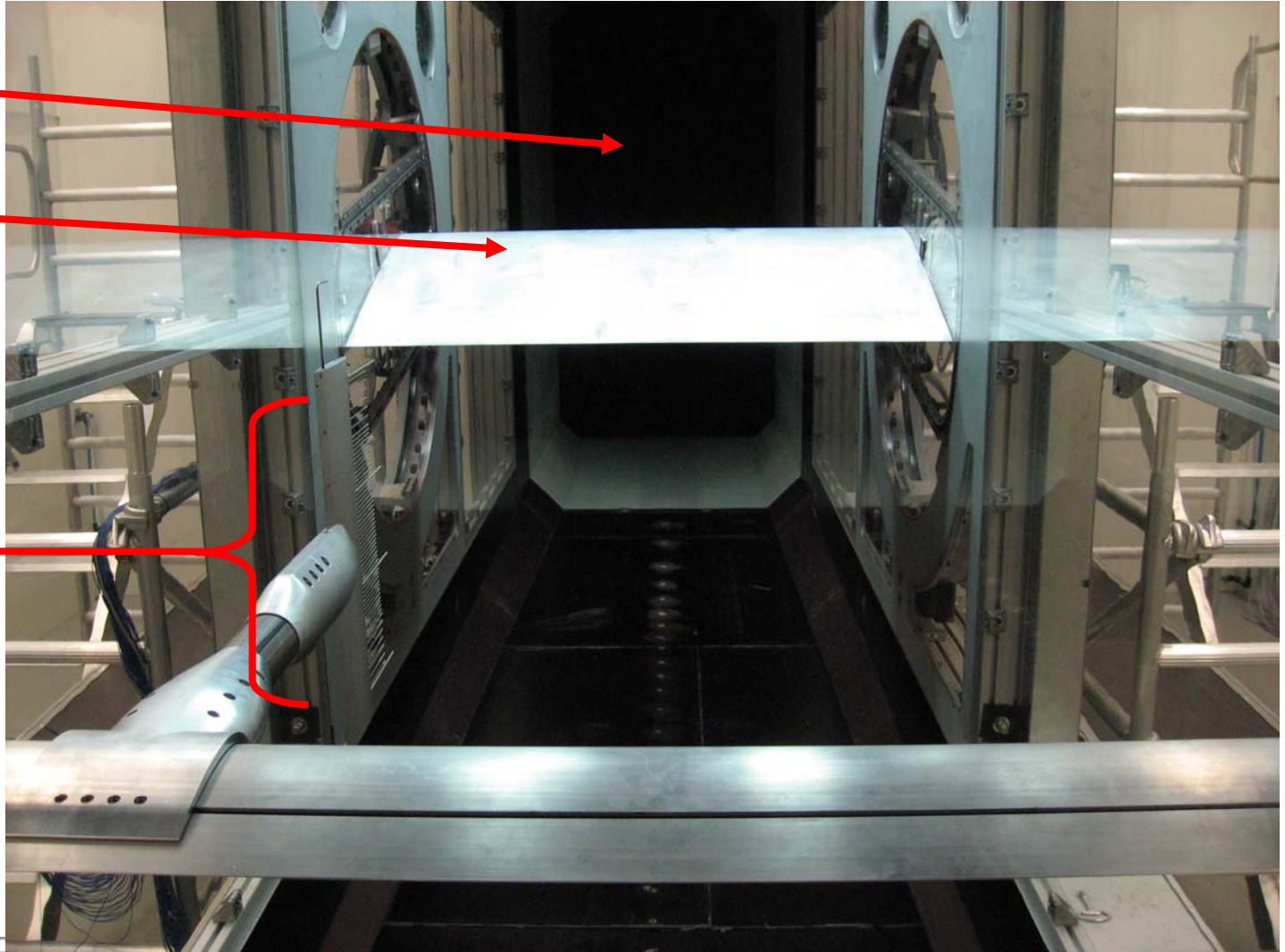
Experimental activities: Risø-C2-18 in LM tunnel

Inlet

Airfoil
 $c=0.90\text{m}$
(2.95ft)

Wake rake:
Measure-
ment of
drag using
traversing

Flow speed:
 $26.7\text{--}100\text{m/s}$
(88–328 ft/s)
 $\text{Re}=1.6\text{mio} -$
 6mio



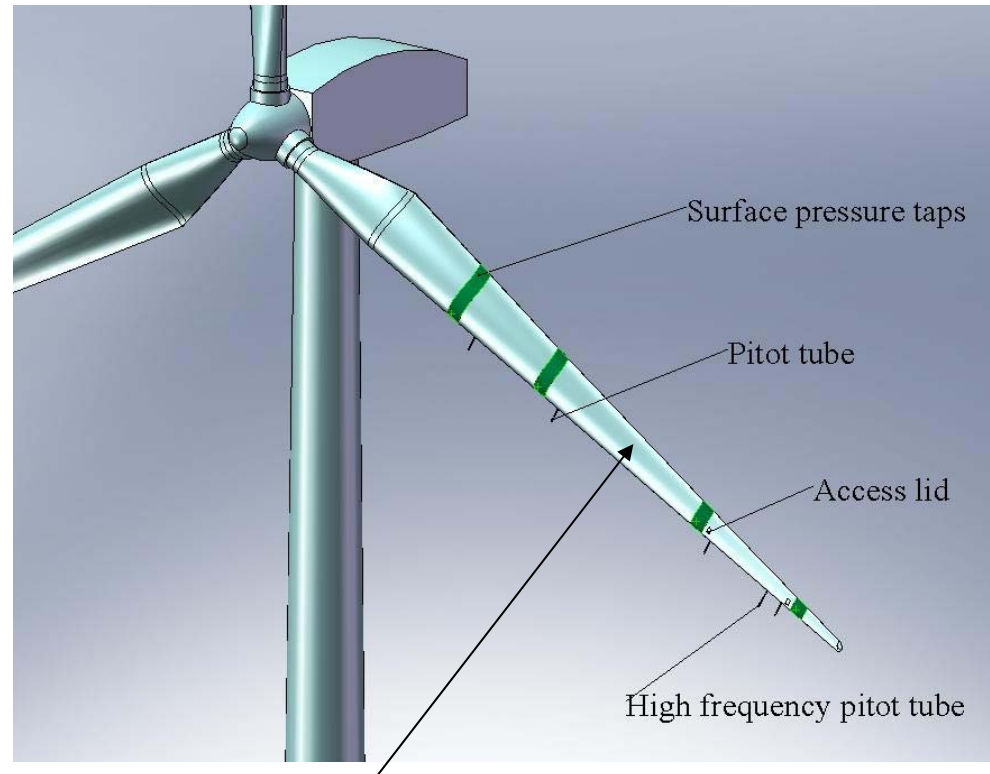
Risø DTU
National Laboratory for

Experimental activities: DAN-AERO 2008 MW-exp.

High frequency pressure and inflow measurements on a NM80, 2.3 MW turbine and in wind tunnel.

Test blade instrumented to study the subjects:

- 2D/3D airfoil characteristics.
- **Boundary layer transition in 2D/3D.**
- **Inflow shear and high frequency turbulence.**
- Dynamic induction.
- Wake flow characteristics.
- Inflow- and trailing edge noise.



4 sections
250 pressure taps
60 microphones
30 strain gauges
10 accelerometers

Summary

- Different tools have been developed during the years
 - **HAWTOPT**: Numerical optimization of blades and wind turbines using aerodynamic and aeroelastic codes
 - **AIRFOILOPT**: Numerical optimization of airfoils using advanced flow simulation
 - **EllipSys3D**: Computational Fluid Dynamics (CFD), e.g. for evaluation of rotor aerodynamics
 - **HAWC2**: Aeroelastic calculations of complete wind turbines including advanced structures and assuming large deflections
 - **HAWCStab**: Computation of aeroelastic stability with the turbine eigen modes and frequencies